

Dynamic Real-Time Deformations

using

Space & Time Adaptive Sampling

Gilles Debunne Mathieu Desbrun

Marie-Paule

Alan H. Barr

Cani



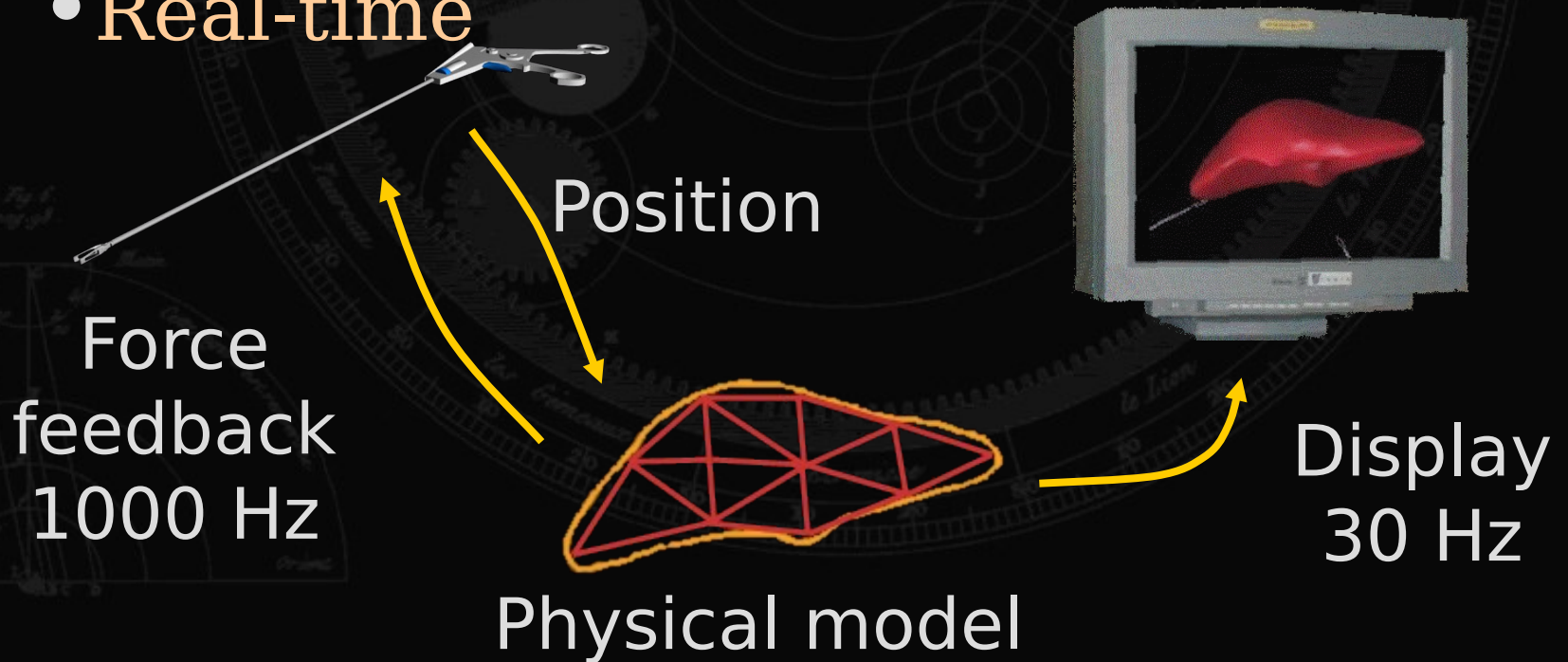
iMAGIS



Goal

Dynamic animation of deformable objects:

- Realistic
- Real-time

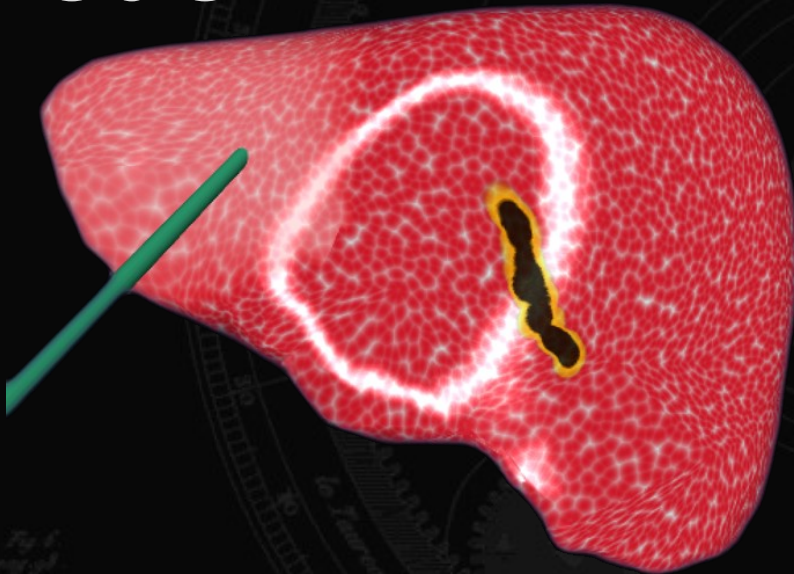


Difficulties

We must combine:

- Visual realism
 - Complex computations
- Haptic feedback, stiff objects
 - Very small time steps (~ 1000 Hz)
- True real-time simulation
 - 1 second of animation computed in 1 second or less

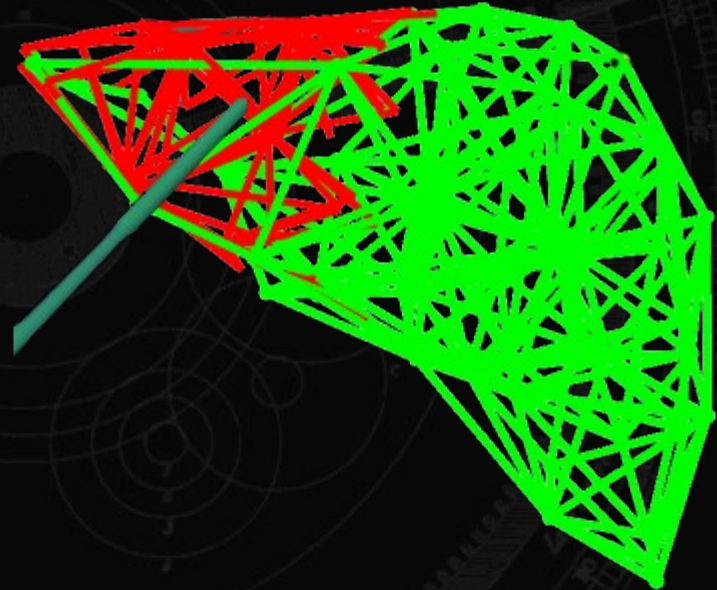
Surface display vs. internal model



Displayed surface

~10,000 triangles

30 Hz

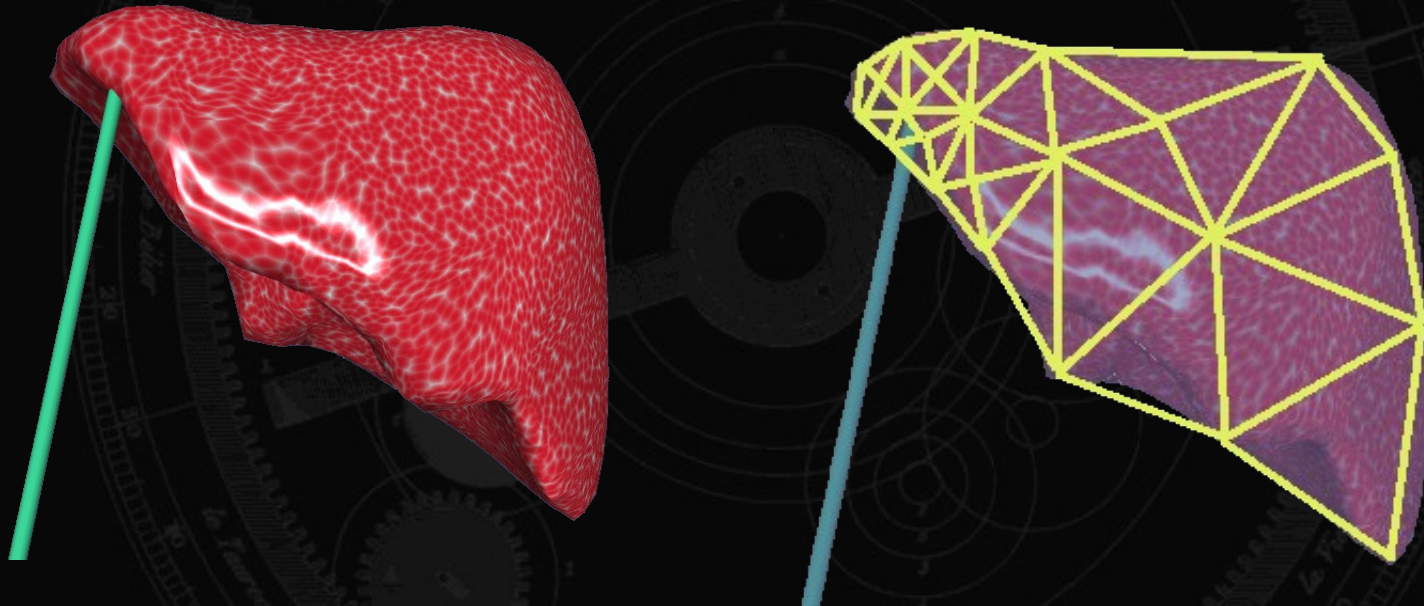


Internal physical model

~100 points

~1000 Hz

Adaptive sampling



High sampling rate in high deformation
zones

Optimal use of the resources

Reach and ensure real-time

Overview

- Multiresolution animation
- Choice of a physical model
- Results

Previous work

Switch techniques according to visual impact

- Dynamic, cinematic...

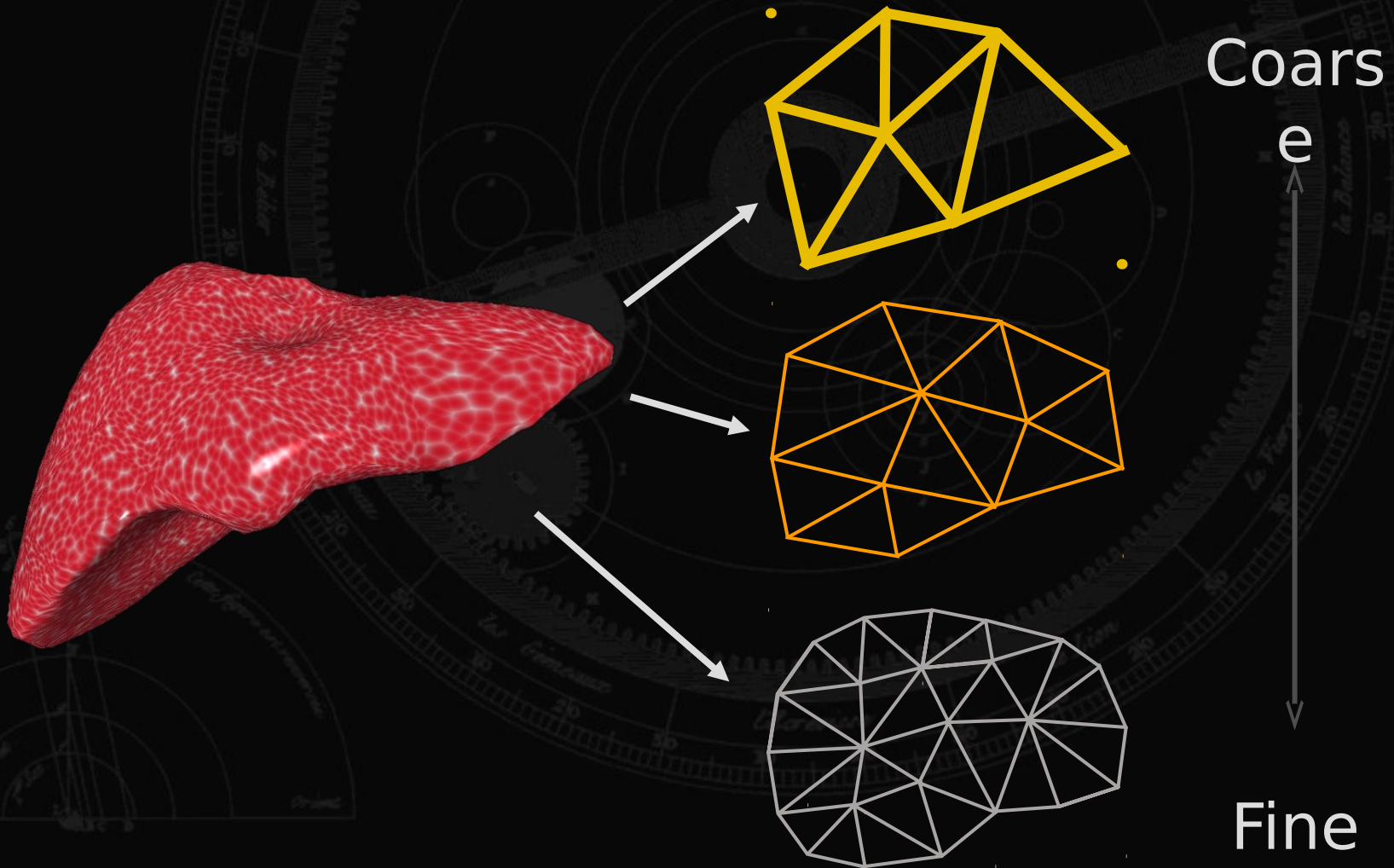
[Berka 97, Cheney & Forsyth 97, Carlson & Hodgins 97]

Adaptive discretization

- Mass-springs [Hutchinson 96, Ganovelli & al 00]
- Finite Elements [O'Brien & Hodgins 99, Zhuang 99]

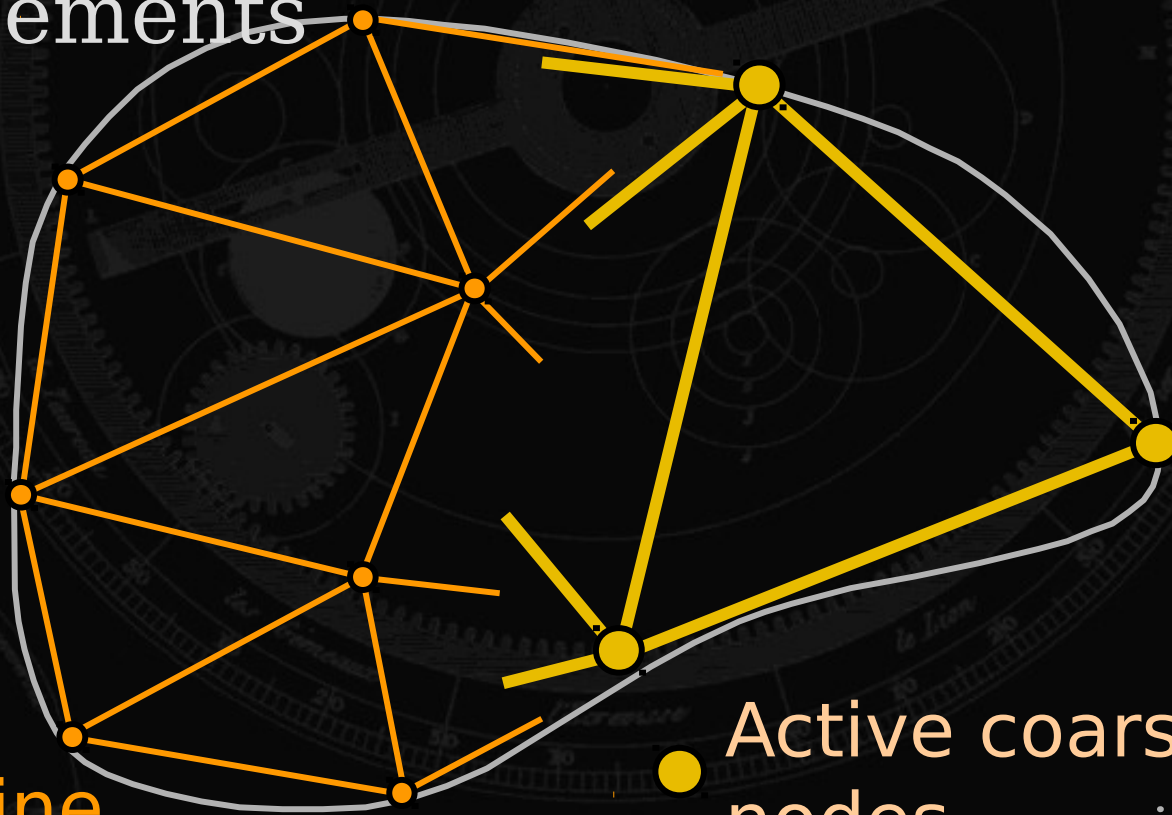
No simplification

Different discretization rates



Active nodes

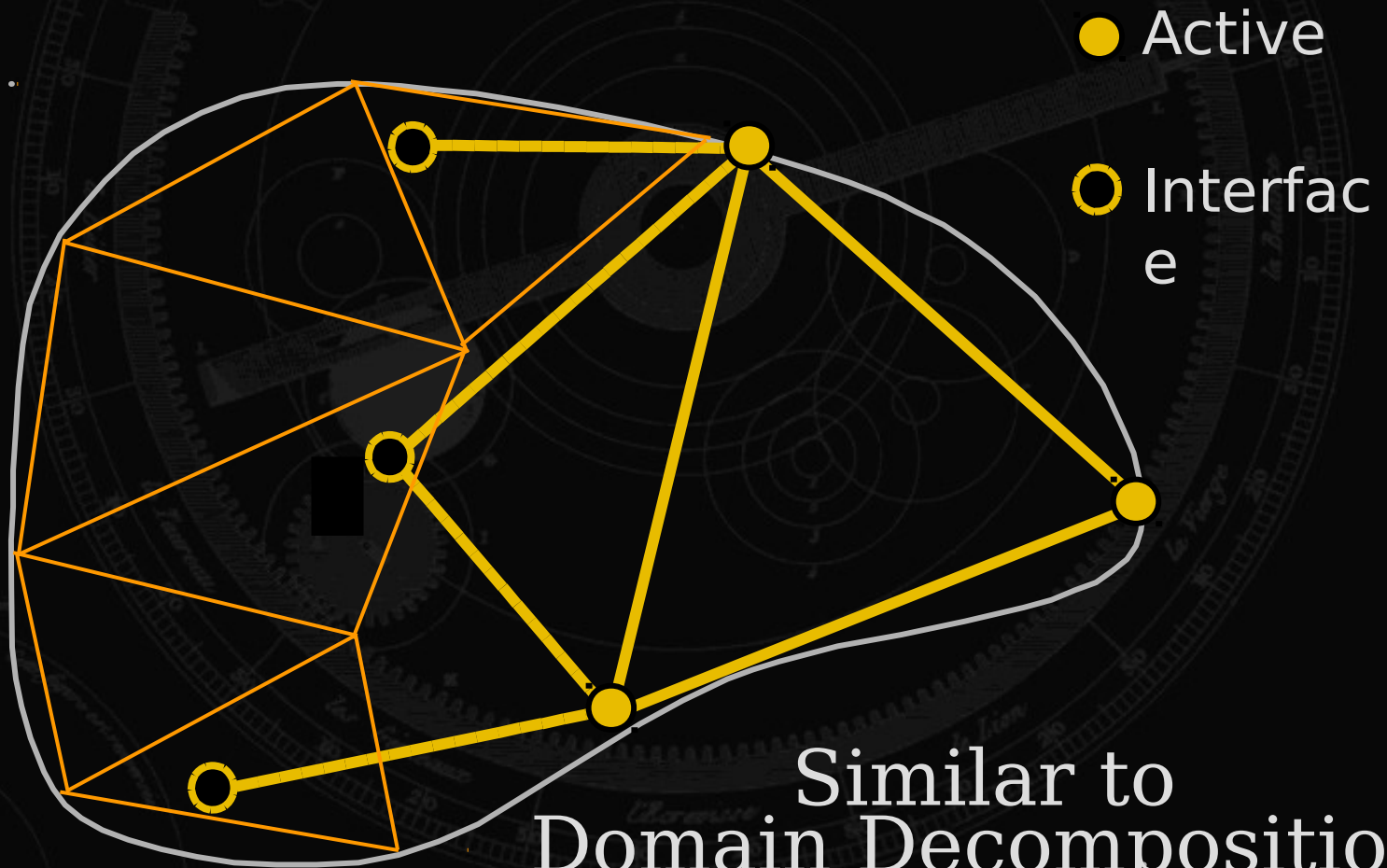
Force computed from neighbors' displacements



• Active fine nodes

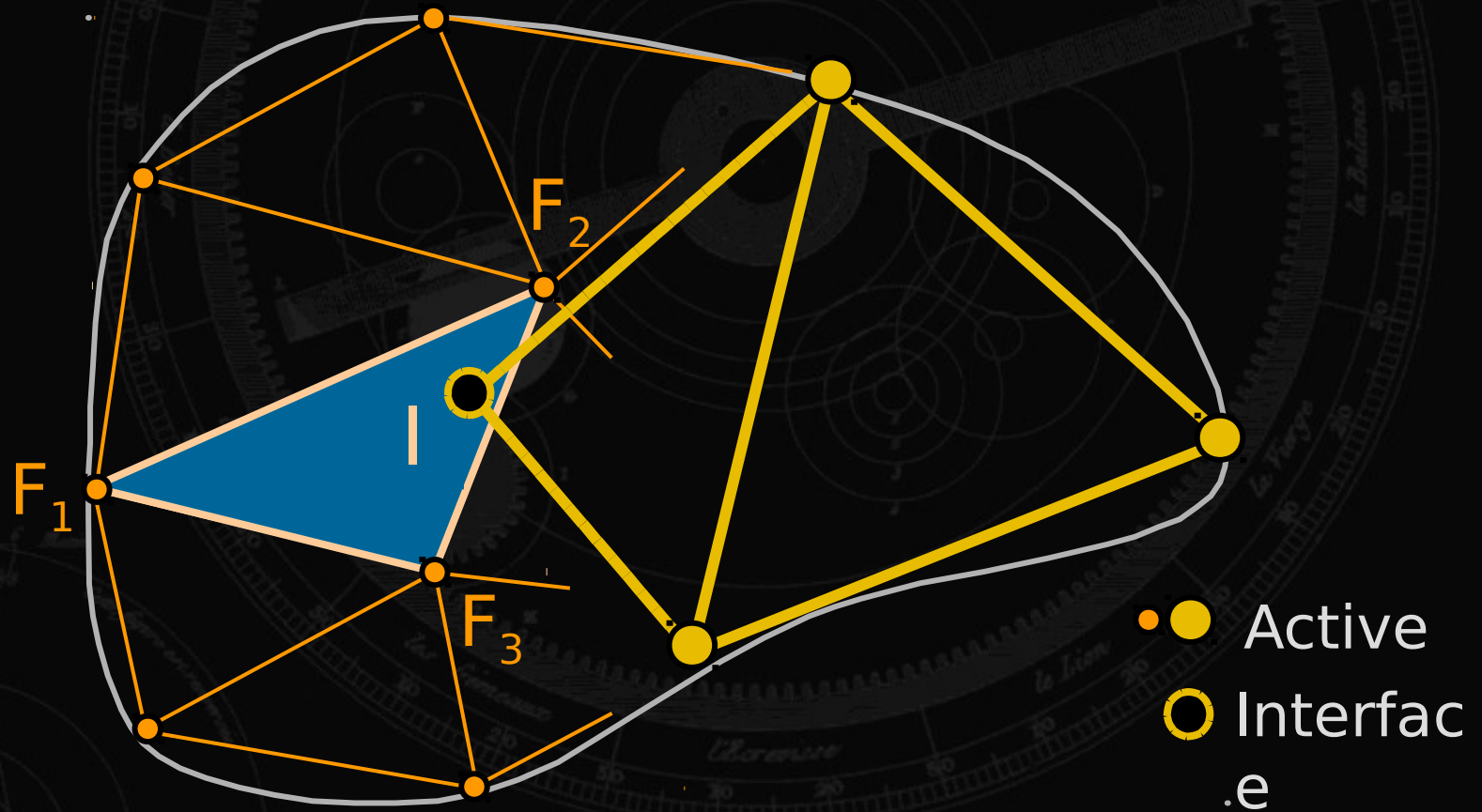
● Active coarse nodes

Interface points



Transmitting deformation information

Fine \longrightarrow Coarse



Sampling adaptation

Based on local deformation amplitude

Node replaced by its **children** in the finer resolution



Children become active

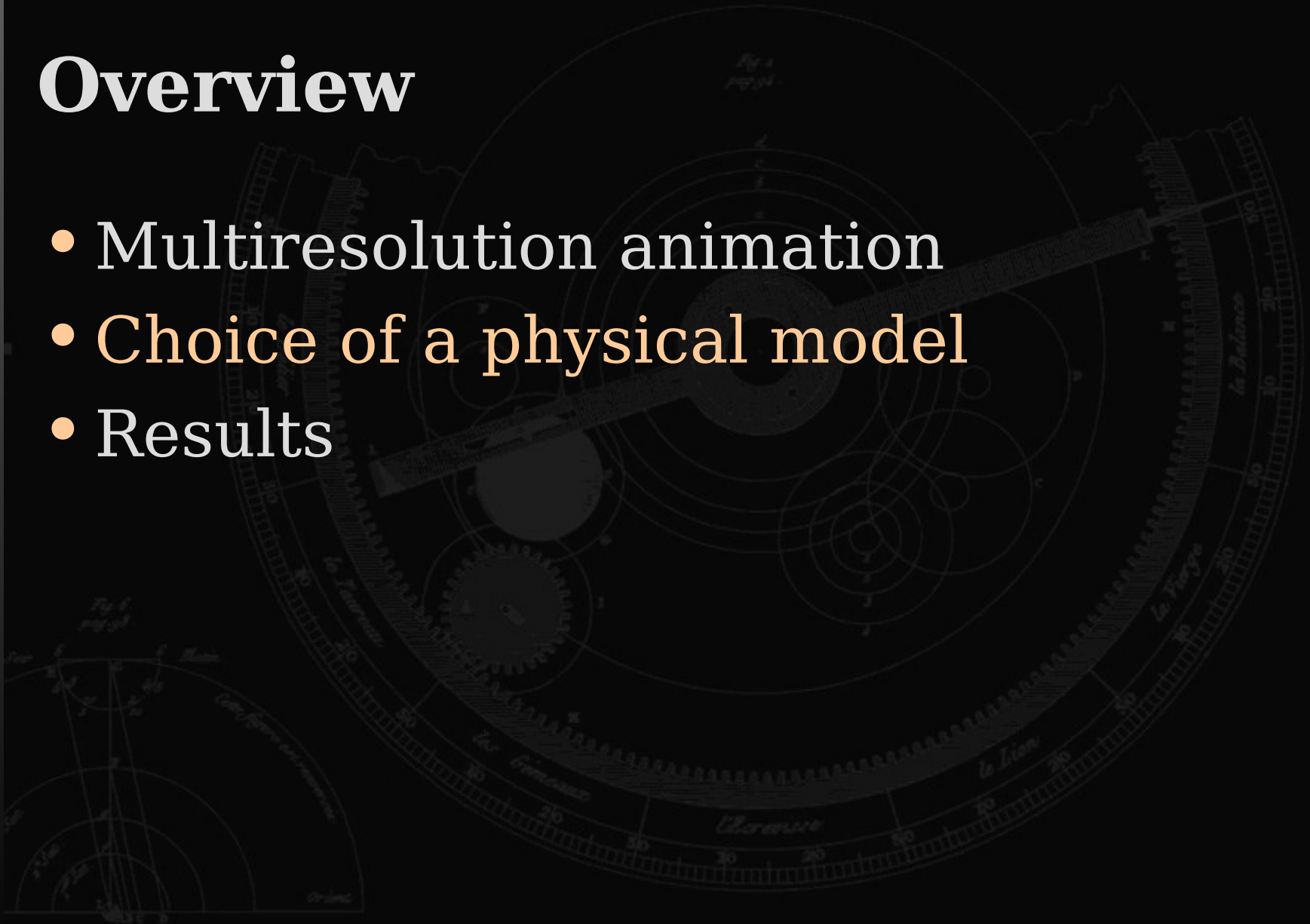


Interface
parent

Active
children

Overview

- Multiresolution animation
- Choice of a physical model
- Results



Goal

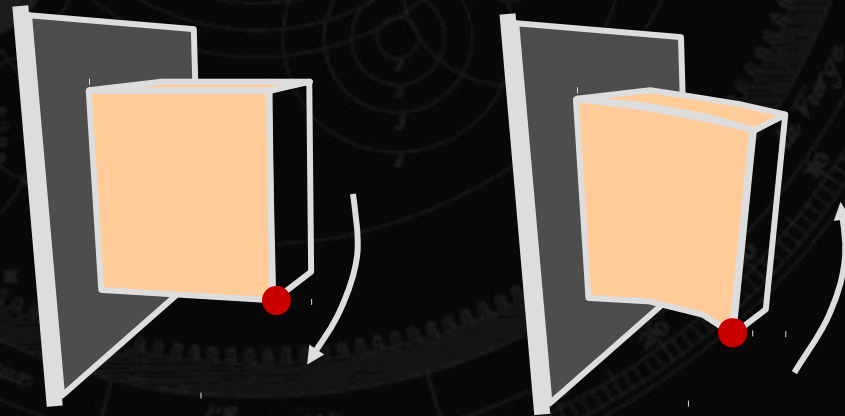
Sampling-independent **dynamic**
simulation

Identical vibration modes

Testbed

No damping

Measure of vertical displacement over



Particle systems

Mass-springs systems

[Hutch96, BW98, GCS00]



Continuous models

Discretization of a continuous equation

- Stress and strain tensors (Cauchy, Green)

Finite Elements [TW88, GMTT89,
BNC96, JP99]

Explicit Finite Elements [Cot97,
OH99]

Continuous models

Discretization of a continuous equation

- Stress and strain tensors (Cauchy, Green)

Finite Elements [TW88, GMTT89,
BNC96, JP99]

Explicit Finite Elements [Cot97,
OH99]

Continuous models

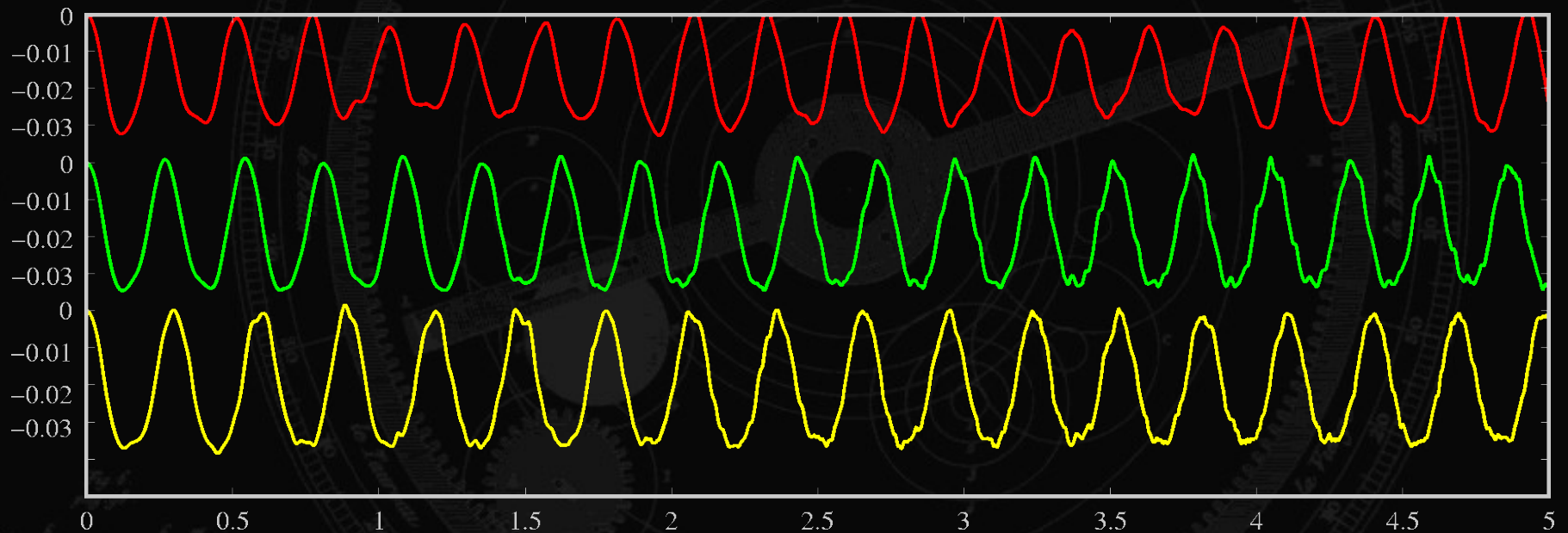
Discretization of a continuous equation

- Stress and strain tensors (Cauchy, Green)

Finite Elements [TW88, GMTT89,
BNC96, JP99]

Explicit Finite Elements [Cot97,
OH99]

Green tensor [OH99]



Multiresolution !

(Behaves almost independently of the resolution)

Multiresolution in time

Courant criterion (CFL)

- Depending on material's stiffness, sampling

Stability

- When force integration may diverge

Synchronization with the display

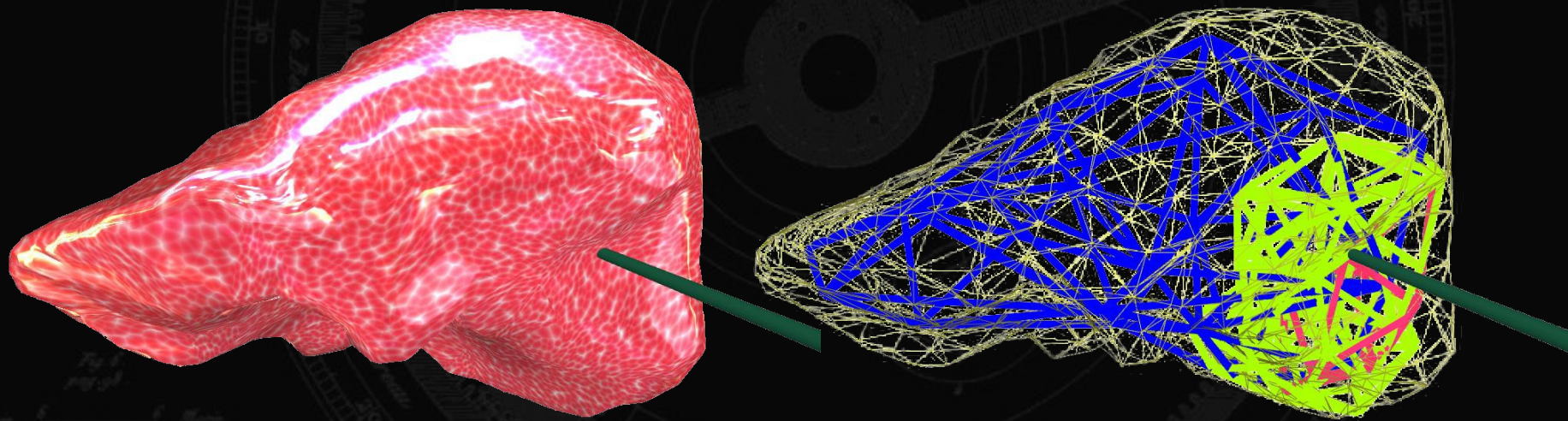
$$dt_i = \frac{dt_{\text{display}}}{2^i}$$

Overview

- Multiresolution animation
- Choice of a physical model
- Results



Results



Conclusion

Multiresolution in physically-based animation

Real-time simulation guaranteed

- **Force feedback at 1000 Hz**
- **Display at 30 Hz**
- **Multiresolution speedup factor :
5 - 20**

SIGGRAPH

2001 EXPLORE INTERACTION
AND DIGITAL IMAGES

